

**CLAIMS**

1. Micro-mirror made up of a moving part (10), with a reflective zone (17), a fixed part (14) a means of connection (13) of the moving part (10) to the fixed part (14), forming an axis of rotation (12) contained in the moving part (10) substantially parallel to a principal plane of the moving part (10) and means of electrical control (18) of the rotation of the moving part (10) about the axis (12), characterised by the fact that the means of electrical control (18) include two or more actuators (19) each formed of a fixed electrode (20) which forms part of the fixed part (14) and a moving electrode (21) possessing a free end (21.1) and an end which is connected to a drive arm (23) which is substantially parallel to the axis (12) and emerging from the moving part (10), with the moving electrode (21) being designed to adhere to the fixed electrode (20) from its free end (21.1) when an actuation voltage (V1, V2) is applied between the two electrodes (20,21) of one of the actuators (19). The adhesion occurs over a surface which varies as a function of the voltage applied between the electrodes of the actuator, with the actuators (19) being arranged on either side of the axis (12).

2. Micro-mirror according to claim 1, wherein the means of connection of the moving part (10) to the fixed part (14) are two torsion arms (13) emerging from the moving part (10) whose ends (11) are connected to the fixed part (14).

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3. Micro-mirror according to claim 1, wherein the axis (12) passes through the geometric centre of the moving part (10).

4. Micro-mirror according to claim 2, wherein, on the same side of the moving part (10) a drive arm (23) is offset in relation to a torsion arm (13).

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5. Micro-mirror according to claim 2, wherein, on the same side of the moving part (10) a drive arm (23) and a torsion arm (13) are an extension of each other.

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6. Micro-mirror according to claim 5, wherein the torsion arm (13) has a transverse section that is less than that of the drive arm (23).

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7. Micro-mirror according to claim 5, wherein the torsion arm (13) has a transverse section that is substantially equal to that of the drive arm (23).

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8. Micro-mirror according to claim 1, wherein several moving electrodes (21) are linked to the same drive arm (23).

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9. Micro-mirror according to claim 1, wherein each drive arm (23) is integral with a single moving electrode (21).

10. Micro-mirror according to claim 1, wherein several moving electrodes (21) located on the same side of the axis (12) are linked together at their free end (21.1).

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11. Micro-mirror according to claim 1, wherein at least one moving electrode (21) is wound on itself, with its free end (21.1) located in a central area of the winding.

12. Micro-mirror according to claim 1, wherein at least one moving electrode (21) is substantially rectilinear.

13. Micro-mirror according to claim 1, wherein at least one moving electrode (21) includes a body (21.2) of substantially constant width extending by means of a stub (21.3) at its free end (21.1), the width of the stub (21.3) being greater than that of the body (21.2).

14. Micro-mirror according to claim 1, wherein the fixed electrodes (20) of the actuators (19) are combined.

15. Micro-mirror according to claim 1, wherein the fixed part (14) includes a base (16) and columns (15) on which rest the means (13) of connection, with the moving part (10) being suspended above the base (16).

16. Micro-mirror according to claim 15, wherein the base (16) includes a cavity (26) opposite the moving part (10) which is suspended above the cavity (26).

17. Micro-mirror according to claim 1, wherein the fixed electrodes (20) are covered with a dielectric material (24).

18. Micro-mirror according to claim 1, wherein the means of electrical control (18) include an addressing device (27) capable of applying an actuation voltage ( $V_1$ ,  $V_2$ ) to the moving electrodes and/or the fixed electrodes.

19. Micro-mirror according to claim 18, wherein the actuation voltage is a continuous voltage ( $V_0$ ) added to a variable control voltage ( $V_1'$ ,  $V_2'$ ).

20. Micro-mirror according to claim 18, wherein at least one fixed electrode (20) of an actuator is divided into two portions (20.1, 20.2) one of which is an end portion (20.1), with these two portions (20.1, 20.2) being insulated from each other, with the addressing device (27) being capable of applying a continuous voltage (V0) to the end portion (21.1) and a variable control voltage (V1', V2') to the other portion (20.2).

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21. Micro-mirror according to claim 19, wherein the continuous voltage (V0) is a minimal voltage for maintaining adhesion of the free end (21.1) of the moving electrode (21) of the actuator onto the fixed electrode (20).

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22. Micro-mirror according to claim 19, wherein when the control voltage applied to an actuator located on one side of the axis is non-zero, the control voltage applied at the same time to an actuator located on the other side of the axis is zero.

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23. Process for the manufacture of a micro-mirror according to claim 1, wherein it includes the following steps:

a) etching of the outline of a first region of the moving part (1), of a first region of the fixed part (14), a first region of the drive arms (23) and of a first region of the means (13) of connection in a surface layer (103) and a first insulating layer (102.2) of a stratified substrate (100) made up of an alternating stacking of a first and second layer (102.1, 102.2) of insulating material and two semi-conductive layers (103, 102.3) one of which is intermediate (102.3) and the other of which is a surface layer (103).

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b) in a second semi-conductive substrate (200) the etching of a recessed part (201), with this second substrate (200) contributing to the formation of a second region of the fixed part (14) and the fixed electrodes (20) of the actuators (19),

c) assembly of two substrates (100, 200) with the recessed part (201) facing the etched surface layer,

d) etching of the outline of the moving electrodes (21), of a second region of the moving part (10), a second region of the means of connection (13) and of a second region of the drive arms (23), in the intermediate layer (102.3) and prior metallization (110,111) electrically connected to moving electrodes (21) for the application of the actuation voltage (V1, V2) of each actuator (19) via the fixed part (14) and the moving part (10).

24. Process according to claim 23, wherein trenches of insulation (104, 105) are made during step a) in the surface layer (103) and in the upper insulation layer (102.2) at the first region of the fixed part (10) and the first region of the moving part (14) and in the intermediate layer (102.3) during step d) at the moving electrodes (21) and the second region of the moving part (10) to provide electrical insulation of the moving electrodes (21) during the application of actuation voltage to a moving electrode (21) via the first region of the fixed part (14) and the first region of the moving part (10).

25. Process according to claim 23, wherein step b) includes the etching of the cavity (26) in a central part of the recessed part (201).

26. Process according to claim 23, wherein step b) is followed by a step for the creation of a layer of insulating material (203) on the second etched substrate (200).

5           27. Process according to claim 23, wherein the second region of the moving part (10) forms the reflective zone (17).

10           28. Process according to claim 23, wherein it includes a step for metallization of the second region of the moving part (10) in order to form the reflective zone (17).

15           29. Process according to claim 23, wherein, after assembly, the second insulating layer (102.2) is removed.

          30. Process according to claim 23, wherein the surface layer (103) is thicker than the intermediate layer (102.3).

20           31. Process according to claim 23, wherein the first substrate is a double SOI substrate and includes next to the second insulating layer (102.2) a semi-conductive base layer (101) which is removed after assembly of the two substrates (100, 200).

25           32. Micro-lens made up of a moving part (10), with a refringent zone (17) a fixed part (14) a means of connection (13) of the moving part (10) to the fixed part (14), forming an axis of rotation (12) contained in the moving part  
30           (10) and means of electrical control (18) of the rotation of the moving part (10) about the axis (12), wherein means of electrical control (18) include two or more actuators (19) each formed of a fixed electrode (20) which forms part of the

fixed part (14) and a moving electrode (21) possessing a free end (21.1) and an end which is connected to a drive arm (23) which is substantially parallel to the axis (12) and emerging from the moving part (10), with the moving electrode (21) being designed to adhere to the fixed electrode (20) from its free end (21.1) when an actuation voltage (V1, V2) is applied between the electrodes (20.21) of one of the actuators (19), the adhesion occurring over a surface which varies as a function of the voltage applied between the electrodes of the actuator, with the actuators (19) being arranged on either side of the axis (12).

33. Micro-lens according to claim 32, wherein the means of connection of the moving part (10) to the fixed part (14) are two torsion arms (13) emerging from the moving part (10) whose ends (11) are connected to the fixed part (14).

34. Micro-lens according to claim 32, wherein the axis (12) passes through the geometric centre of the moving part (10).

35. Micro-lens according to claim 33, wherein, on the same side of the moving part (10) a drive arm (23) is offset in relation to a torsion arm (13).

36. Micro-lens according to claim 33, wherein, on the same side of the moving part (10) a drive arm (23) and a torsion arm (13) form an extension of each other.

37. Micro-lens according to claim 36, wherein the torsion arm (13) has a transverse section that is less than that of the drive arm (23).



38. Micro-lens according to claim 36, wherein the torsion arm (13) has a transverse section that is substantially equal to that of the drive arm (23).

5           39. Micro-lens according to claim 32, wherein several moving electrodes (21) are linked to the same drive arm (23).

10           40. Micro-lens according to claim 32, wherein each drive arm (23) is integral with a single moving electrode (21).

15           41. Micro-lens according to claim 32, wherein several moving electrodes (21) located on the same side of the axis (12) are linked together at their free end (21.1).

20           42. Micro-lens according to claim 32, wherein at least one moving electrode (21) is wound on itself, with its free end (21.1) located in a central area of the winding.

          43. Micro-lens according to claim 32, wherein at least one moving electrode (21) is substantially rectilinear.

25           44. Micro-lens according to claim 32, wherein at least one moving electrode (21) includes a body (21.2) of substantially constant width extending by means of a stub (21.3) at its free end (21.1), the width of the stub (21.3) being greater than that of the body (21.2).

30           45. Micro-lens according to claim 32, wherein the fixed electrodes (20) of the actuators (19) are combined.



46. Micro-lens according to claim 32, wherein the fixed part (14) includes a base (16) and columns (15) on which the means (13) of connection (13) rest, with the moving part (10) being suspended above the base (16).

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47. Micro-lens according to claim 46, wherein the base (16) includes a cavity (26) opposite the moving part (10) which is suspended above the cavity (26).

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48. Micro-lens according to claim 32, wherein the fixed electrodes (20) are covered with a dielectric material (24).

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49. Micro-lens according to claim 32, wherein the means of electrical control (18) include an addressing device (27) capable of applying an actuation voltage ( $V_1$ ,  $V_2$ ) to the moving electrodes and/or the fixed electrodes.

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50. Micro-lens according to claim 49, wherein the actuation voltage is a continuous voltage ( $V_0$ ) added to a variable control voltage ( $V_1'$ ,  $V_2'$ ).

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51. Micro-lens according to claim 49, wherein at least one fixed electrode (20) of an actuator is divided into two portions (20.1, 20.2) one of which is an end portion (20.1), with these two portions (20.1, 20.2) being insulated from each other, with the addressing device (27) being capable of applying a continuous voltage ( $V_0$ ) to the end portion (21.1) and a variable control voltage ( $V_1'$ ,  $V_2'$ ) to the other portion (20.2).

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52. Micro-lens according to claim 50, wherein the continuous voltage ( $V_0$ ) is a minimal voltage for maintaining

adhesion of the free end (21.1) of the moving electrode (21) of the actuator onto the fixed electrode (20).

53. Micro-lens according to claim 50, wherein,  
5 when the control voltage applied to an actuator located on one side of the axis is non-zero, the control voltage applied at the same time to an actuator located on the other side of the axis is zero.

10 54. Process for the manufacture of a micro-lens according to claim 32, wherein it includes the following steps:

a) etching of the outline of a first region of the moving part (10), of a first region of the fixed part (14), of a first region of the drive arms (23) and of a first region of  
15 the means (13) of connection in a surface layer (103) and a first insulating layer (102.2) of a stratified substrate (100) made up of an alternating stacking of a first and second layer (102.1, 102.2) of insulating material and two semi-conductive layers (103, 102.3) one of which is intermediate (102.3) and  
20 the other of which is a surface layer (103),

b) in a second semi-conductive substrate (200) the etching of a recessed part (201), with this second substrate (200) helping to form a second region of the fixed part (14) and the fixed electrodes (20) of the actuators (19),

25 c) assembly of two substrates (100, 200) with the recessed part (201) facing the etched surface layer,

d) etching of the outline of the moving electrodes (21), of a second region of the moving part (10), a second region of the means of connection (13) and of a second region  
30 of the drive arms (23), in the intermediate layer (102.3) and prior metallization (110,111) electrically connected to moving electrodes (21) for the application of the actuation voltage

(V1, V2) of each actuator (19) via the fixed part (14) and the moving part (10).

55. Process according to claim 54, wherein  
5 trenches of insulation (104, 105) are made during step a) in the surface layer (103) and in the upper insulation layer (102.2) at the first region of the fixed part (10) and the first region of the moving part (14) and in the intermediate layer (102.3) during step d) at the moving electrodes (21)  
10 and of the second region of the moving part (10) to provide electrical insulation of the moving electrodes (21) during the application of actuation voltage to a moving electrode (21) via the first region of the fixed part (14) and the first region of the moving part (10).

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56. Process according to claim 54, wherein step b) includes the etching of the means forming the pivot (30.1) in the recessed part (201).

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57. Process according to claim 54, wherein step b) includes the etching of the cavity (26) in a central part of the recessed part (201).

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58. Process according to claim 54, wherein step b) is followed by a step for the creation of a layer of insulating material (203) on the second etched substrate (200).

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59. Process according to claim 54, wherein the moving part (10) is etched in the form of a frame during step b).

60. Process according to claim 59, wherein it includes a step for assembly of a lenticular refringent

element to the frame of the moving part in order to form the refringent zone (17).

61. Process according to claim 54, wherein, after  
5 assembly in step c), the second insulating layer (102.2) is removed.

62. Process according to claim 54, wherein the  
surface layer (103) is thicker than the intermediate layer  
10 (102.3).

63. Process according to claim 54, wherein the  
first substrate (100) is a double SOI substrate and includes  
next to the second insulating layer (102.2) a semi-conductive  
15 base layer (101) which is removed after assembly of the two  
substrates (100, 200).

**SUMMARY DESCRIPTION**

Micro-mirror or micro-lens made up of a moving  
5 part (10) with a reflective or refringent zone (17), a fixed  
part (14), means of connection (13) of the moving part (10) to  
the fixed part (14) which forms an axis of rotation (12) for  
the moving part (10) and of means for controlling (18) the  
rotation. The means of control include two or more actuators  
10 (19) arranged either side of the axis (12), each formed of a  
fixed electrode (20) forming part of the fixed part (14) and a  
moving electrode (21) possessing a free end (21.1) and an end  
connected to a drive arm (23) which is substantially parallel  
to the axis (12) and emerging from the moving part (10). The  
15 moving electrode (21) adheres to the fixed electrode (20) from  
its free end (21.1) when a voltage is applied to the actuator  
(19), the adhesion is a function of the applied voltage.

Application to optical systems.

20 Figure 5A.